Fabrication and Characterization of Superconducting NbN Nanowire Single Photon Detectors

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Outline

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Introduction and Motivation

- High Speed, Single Photon Detectors have use in communication, quantum optics and CMOS analysis.
- SNSPDs have demonstrated high DEs, low dark-counts, and fast response times.
- Technical challenges include making larger detectors, increasing DE and achieving fast recovery times.

Operation of SNSPD Detectors

- A thin (<5 nm) narrow (<120 nm) NbN wire is current biased just below its critical current.
- The wire is formed into a meander.
- A single photon absorbed in the wire rapidly creates a large number of quasiparticles, which depresses Ic.
- The bias current locally exceeds Ic causing a voltage spike and a drop in the bias current.
- Recovery of the bias current is set by the Kinetic Inductance (L/R time constant).

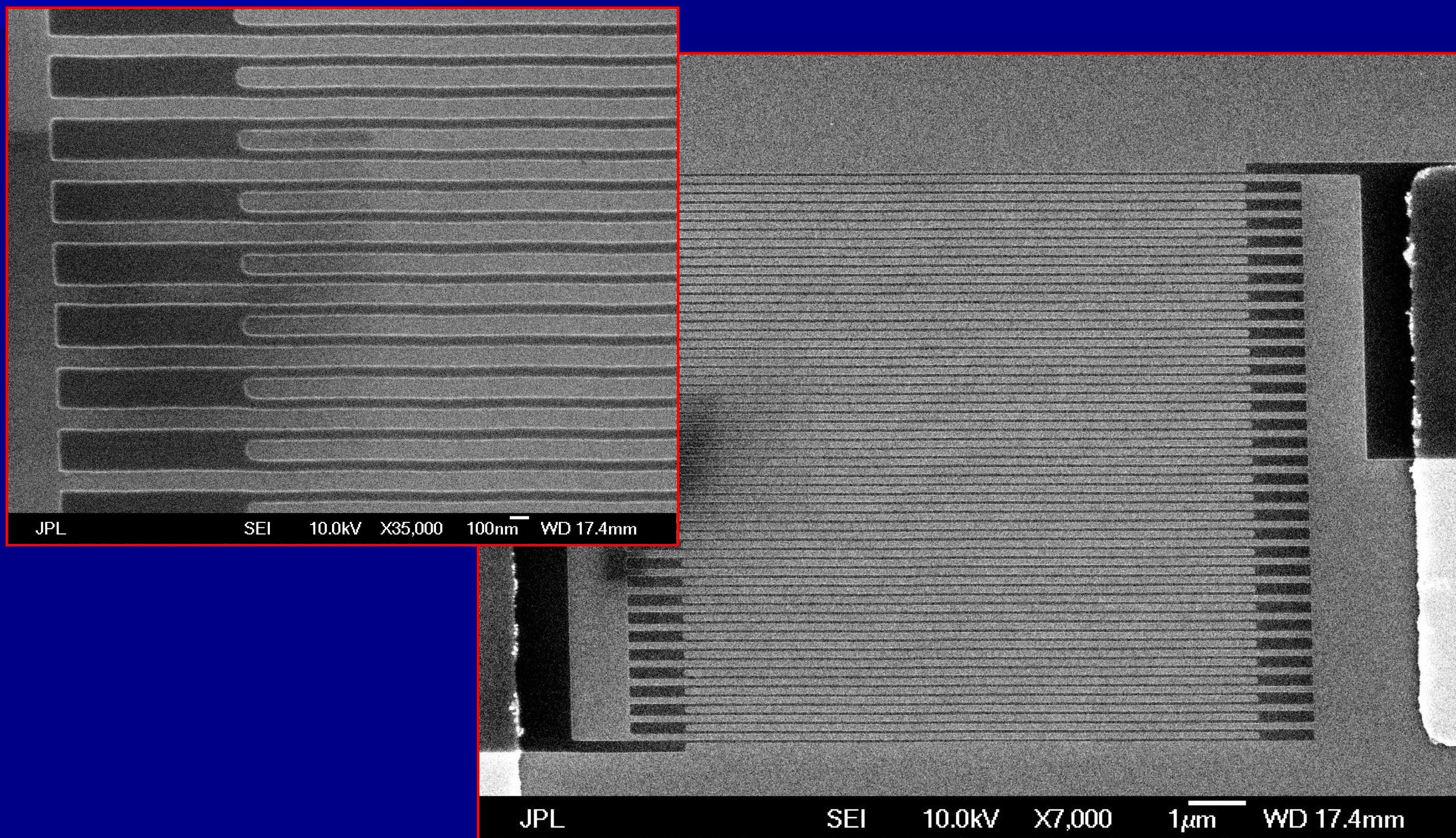
NbTiN Deposition

- C-Axis Quartz and Sapphire are used for their isotropic dielectric constant and high thermal conductivity.
- Deposition is done in a load locked UHV system.
- An MgO buffer layer is used to stabilize the NbN.
- Substrates are heated to 500-600 C.
- NbN is DC magnetron sputtered from a target in an Ar-N_2 mixture.
- RF bias is applied to the substrate to promote smooth film growth.
- Typical films are 500-800 Ohms/square with Tc=10-12 K.

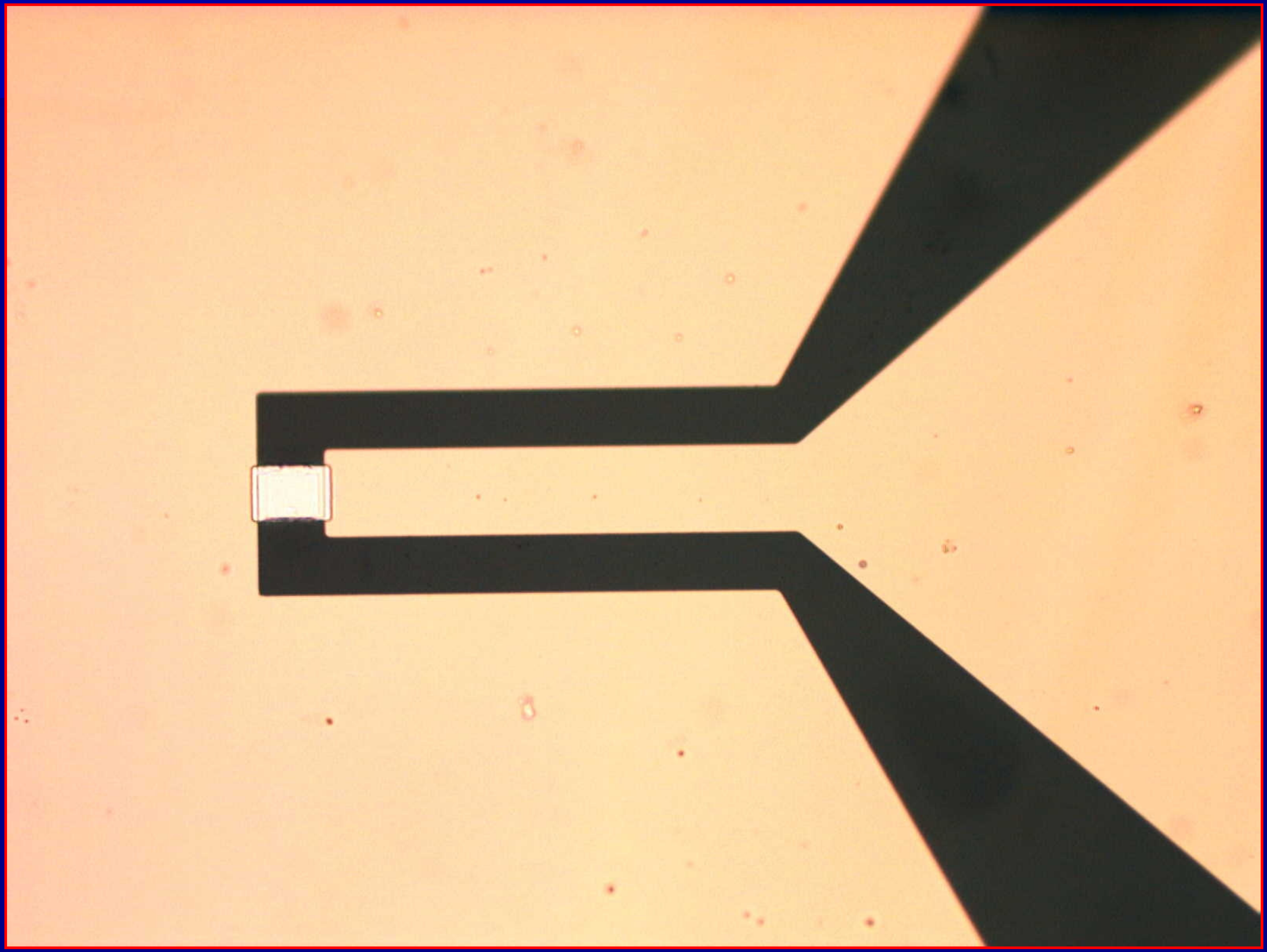
Fabrication Details
(PMMA Process)

- Titanium-Gold wire layers are deposited after a brief Ion mill to improve the interface by liftoff.
- PMMA is written at 100 keV
- First SF_6 etch
- Liftoff SiO-Al which acts as a cavity and etch mask
- Second SF_6 etch
- More Recent devices use HSQ resist

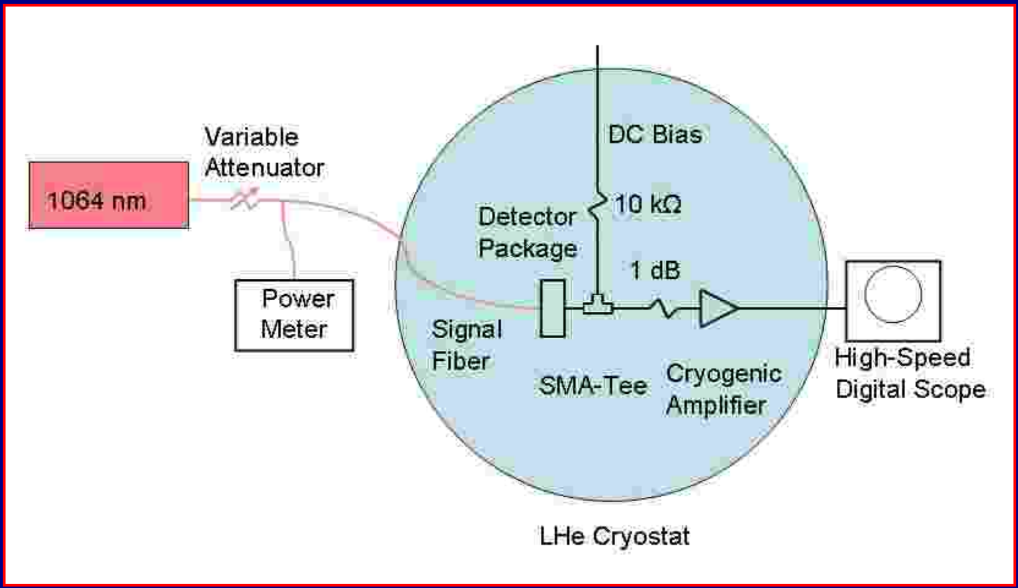
SEM image of a 10 by 10 micron SNSPD with 80 nm wires fabricated using HSQ e-beam resist.

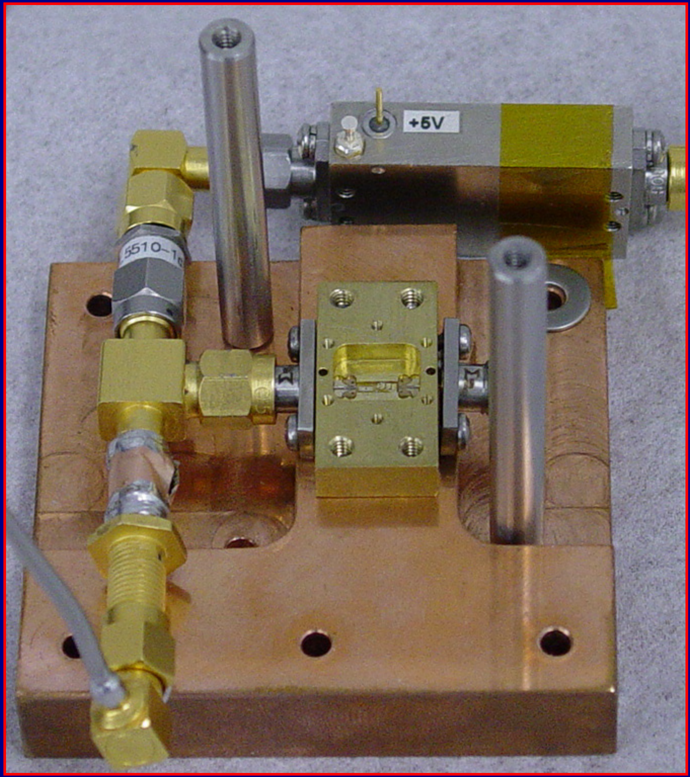


Backside Coupled SNSPD

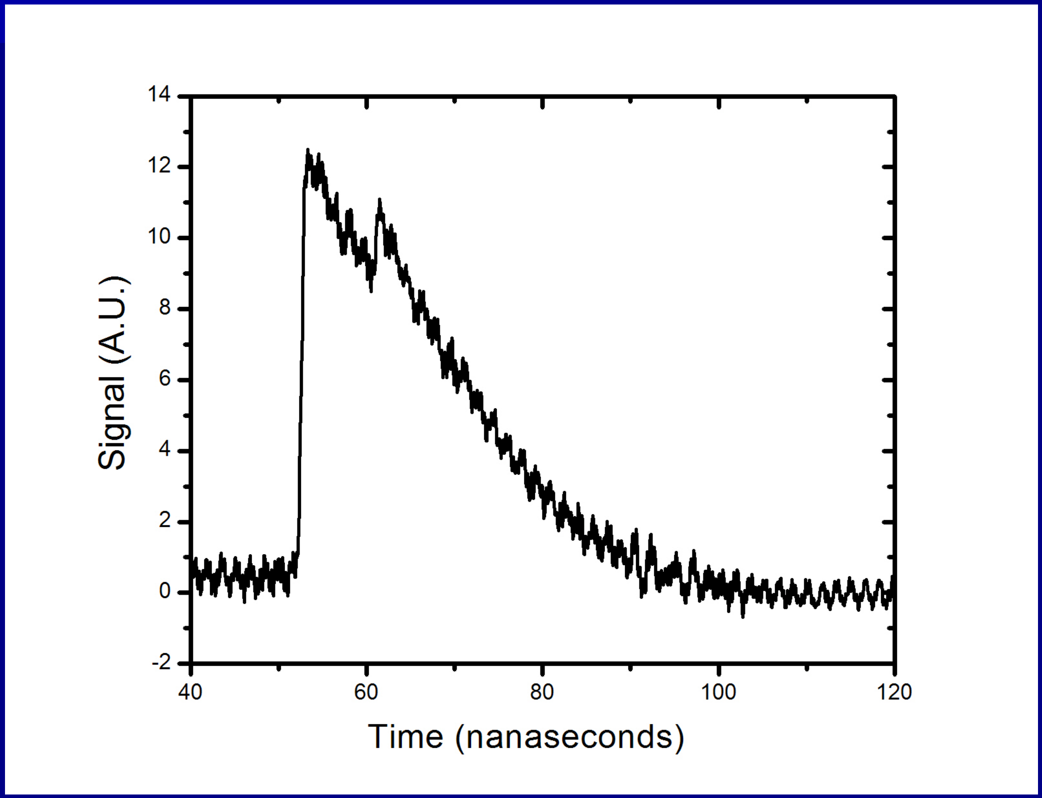


Measurement Apparatus





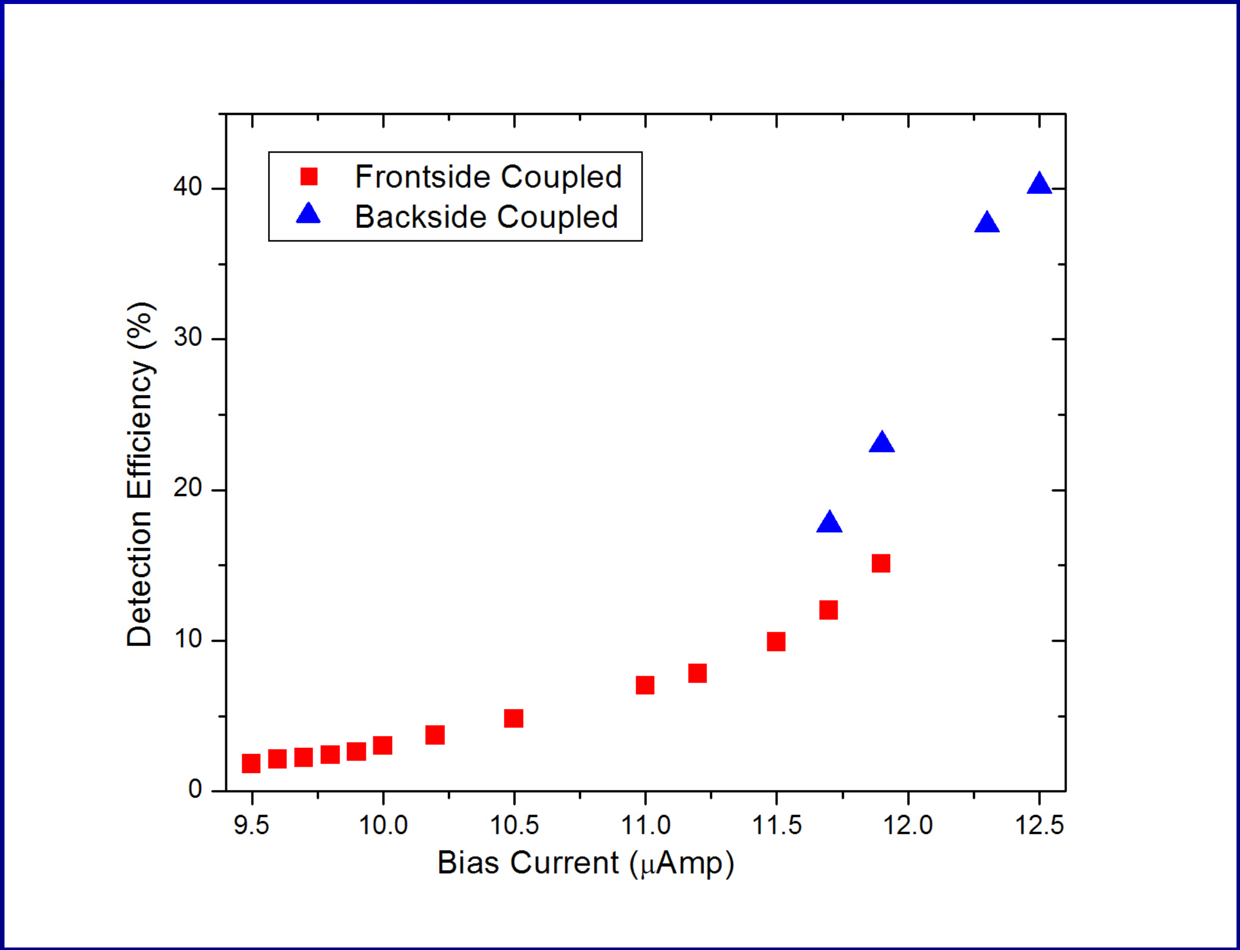
Electrical Response of a 15x15 µm SNSPD to 1064nm radiation



The rise time is 200 ps and the recovery time is 15 ns.

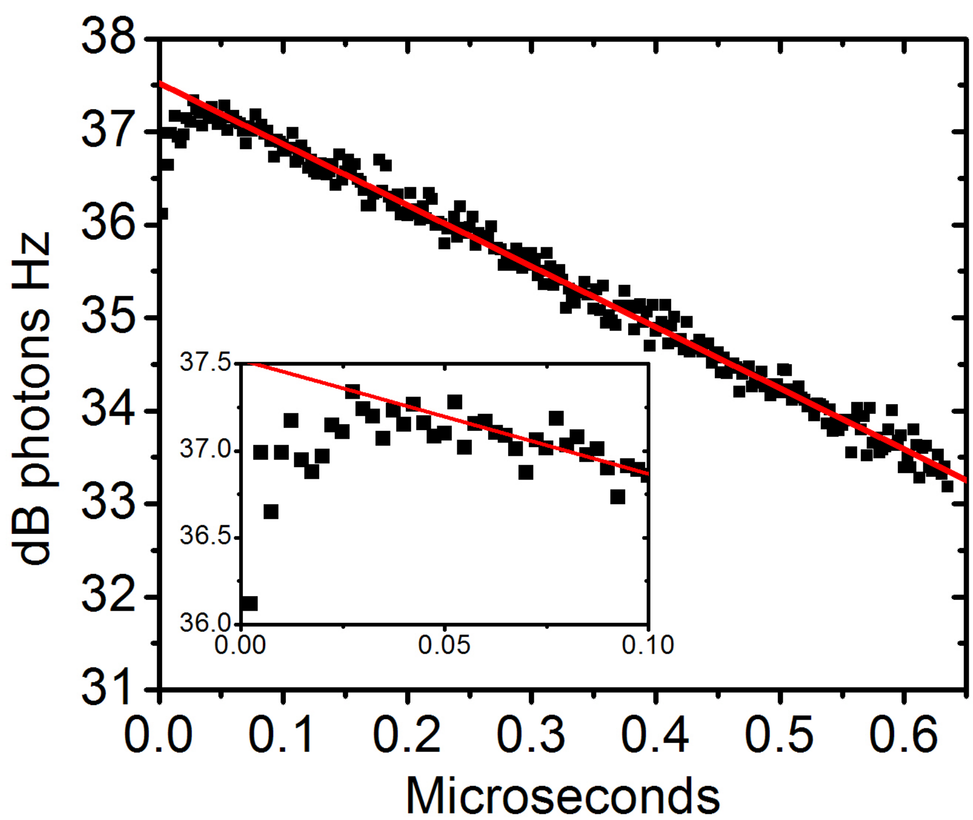
Detector Efficiency vs Bias Current

(15 by 15 µm device 12 nm wires on 24 nm spacing. T=4.2->3.1 K)

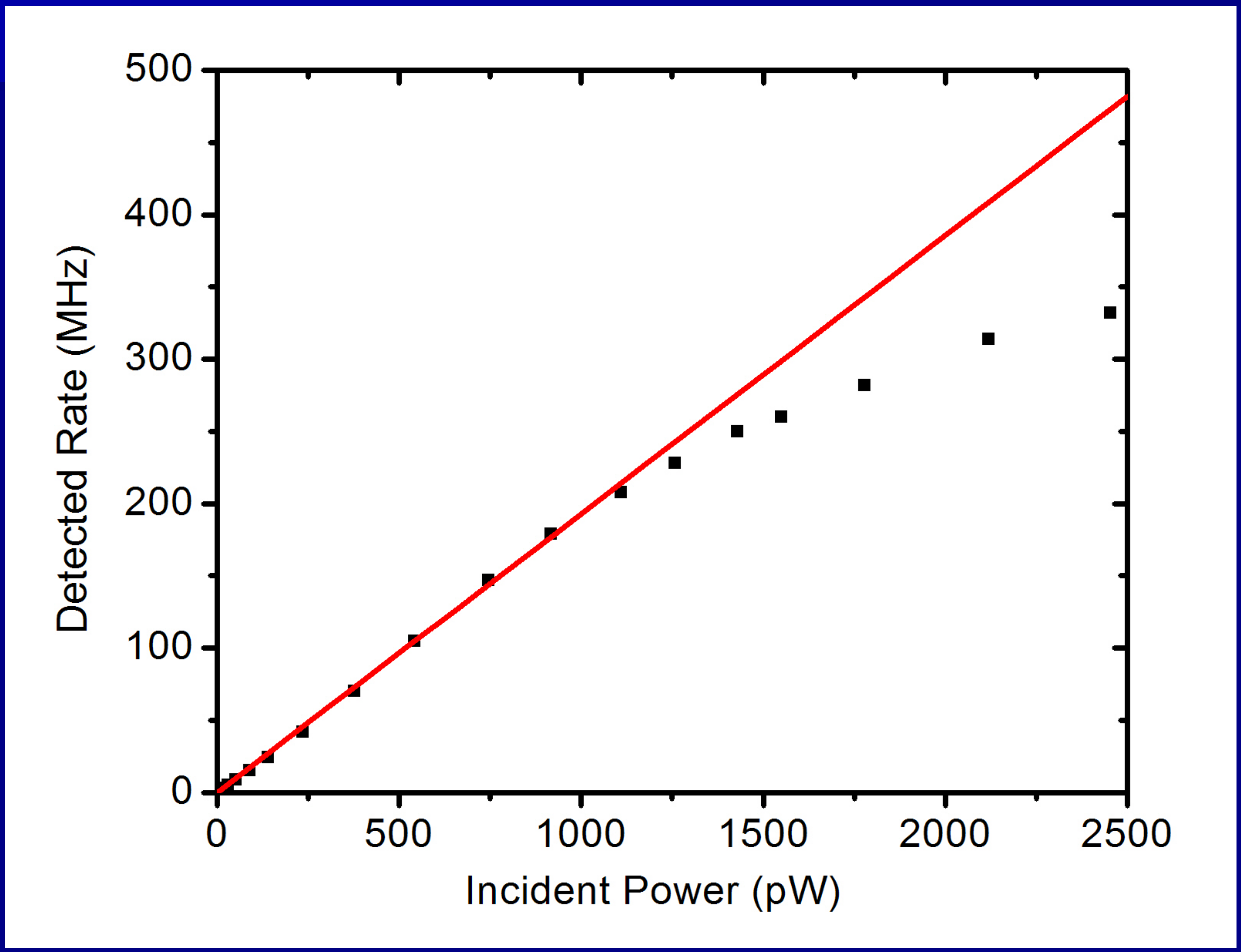


Interarrival Time Plot

(5 by 5 µm device 12 nm wires on 24 nm spacing)



Detector Linearity



Conclusions

- We have fabricated large area SNPDs.
- Detector Efficiencies of 40% were achieved.
- Linearity of detectors is good.
- Recovery times have been measured using interarrival time statistics.

Future Work

- Improve DE (improved uniformity, lower operating temperatures and improved optical cavities.)
- Increase operating speeds using arrays of smaller detectors.
- Demonstrate SNSPDs in optical communication systems.
- Absolute measurement of DE using correlated photons.